STABILIZATION AND UPGRADING OLD TRANSPORTATION TUNNELS

by
Rich Humphries and Mark Sandfort

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Typical Challenges in Upgrading Old Tunnels

- Tunnels are Often In-Service and Must Remain Active
- Maintenance of Old Tunnels is Often Minimal
- Usually there are No As-Built Drawings or Records of Repairs
- Previous Repairs have Often Caused Present Instability
- Increased Clearance is Often Required for More Lanes or Larger Trains

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Typical Construction of Old Tunnels

- Drill-and-Blast or Hand Excavation was used for Original Construction
- Support Installed During Excavation was Usually Minimal
- Lining is Usually Free-Standing – Sometimes with Backfill behind it
- Many have Historically Important Portal Structures

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Typical Conditions in Old Tunnels

- In Good Rock Tunnels were left Bald
- Rock has generally remained stable, except for minor falls
- Shears, Faults and Weathered Zones typically lined with free-standing wood, masonry, brick or unreinforced concrete – conditions of these materials vary
- Voids behind lining left open or backfilled with wood or shot rock
- Lining materials often deteriorate in 50 to 100 years
- Lining is usually not stable in seismic loading

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Constraints in Tunnel Upgrading

- Repairs must often be done in windows of time so that tunnel can remain active or “live”
- Windows often 6 to 10 hours
- Tunnels must be stable and clear at end of Window
- Invert usually cannot be lowered to increase clearance
- Pre-support required before lining can be removed

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CASE HISTORIES

- **Little Tunnel Stabilization, Cumberland Gap, Tennessee**
- **Rockport and Whitehaven Tunnel Clearance Improvement and Stabilization, Pocono Mountains, Pennsylvania**
- **Exchange Place Transit Tunnel Upgrades, NY-NJ**

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LITTLE TUNNEL, CUMBERLAND GAP, TN

100-year old disused Railroad Tunnel converted to a Utility and Pedestrian Tunnel

Tunnel Condition Survey

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Little Tunnel - Profile

Little Tunnel – Initial Collapse of Wooden Sets

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Dead Load on Wooden Sets

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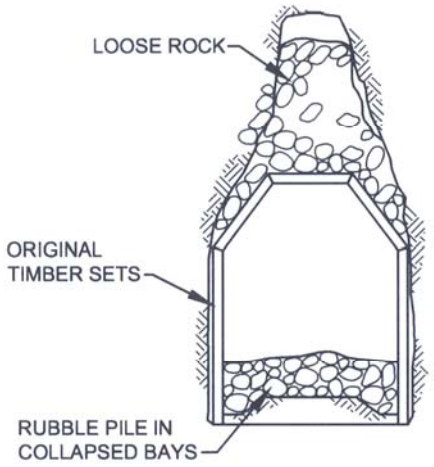
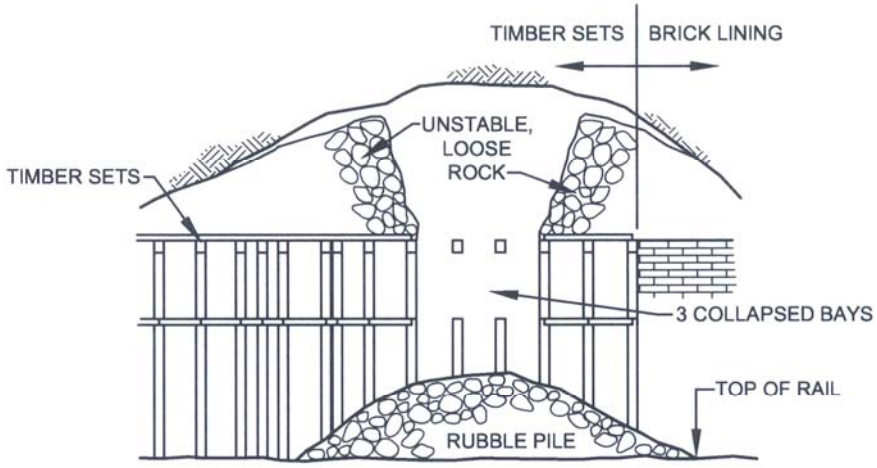
Little Tunnel

Initial Collapse

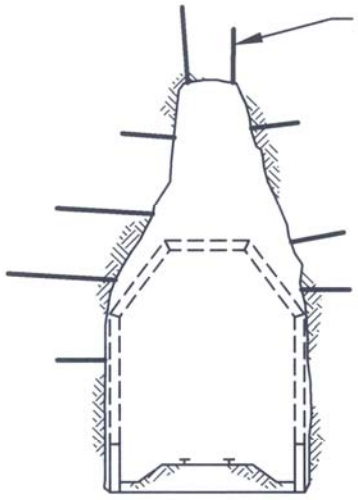


CROSS SECTION



PROFILE THROUGH COLLAPSED ZONE

Initial Repairs



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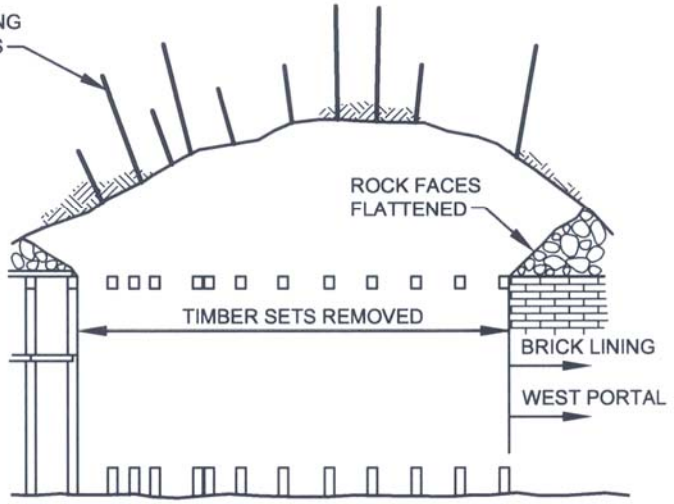

PROFILE THROUGH STABILIZED ZONE

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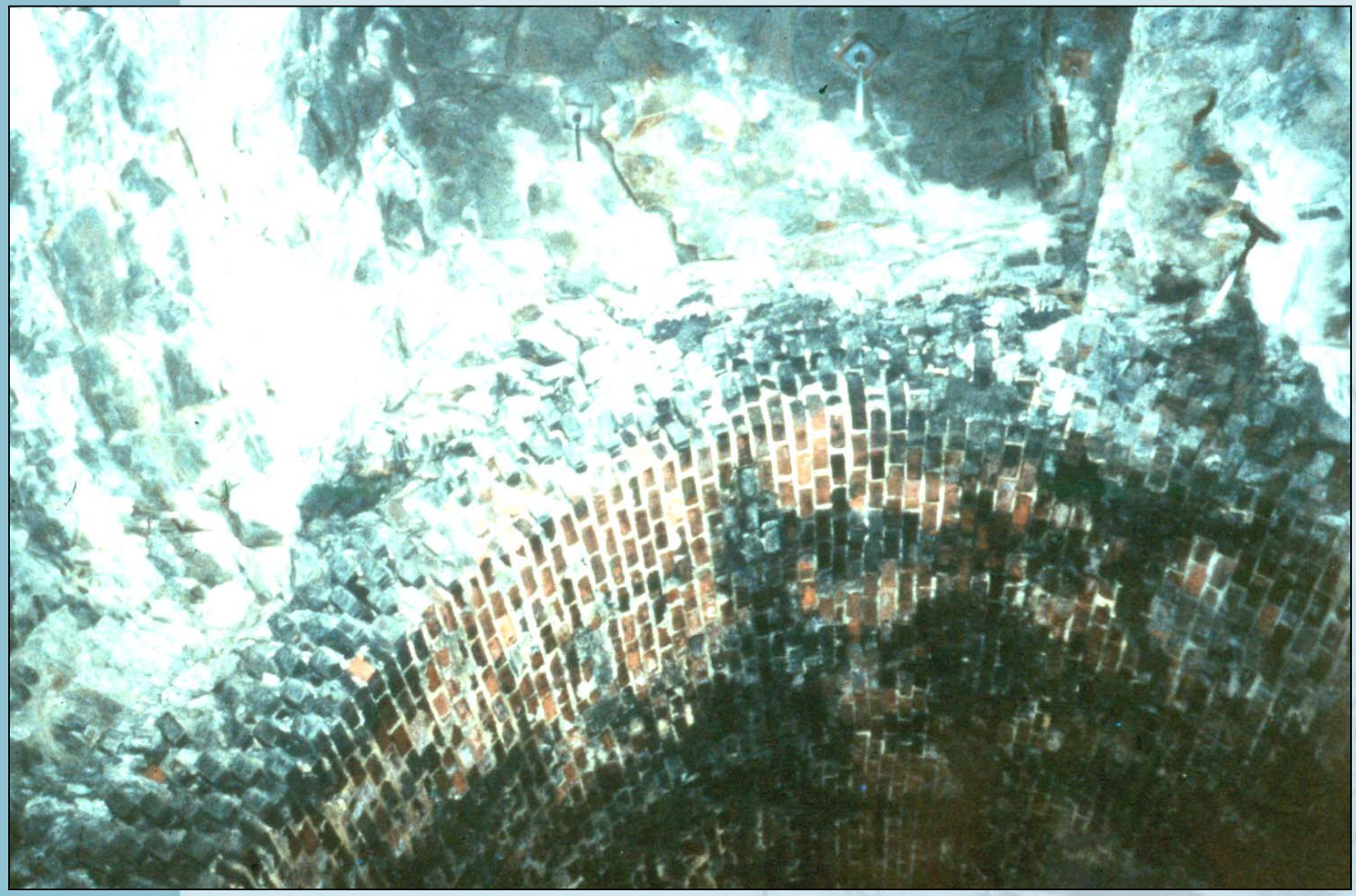
Initial Repairs at End of Brick Lining
Scaling and Rock Bolting



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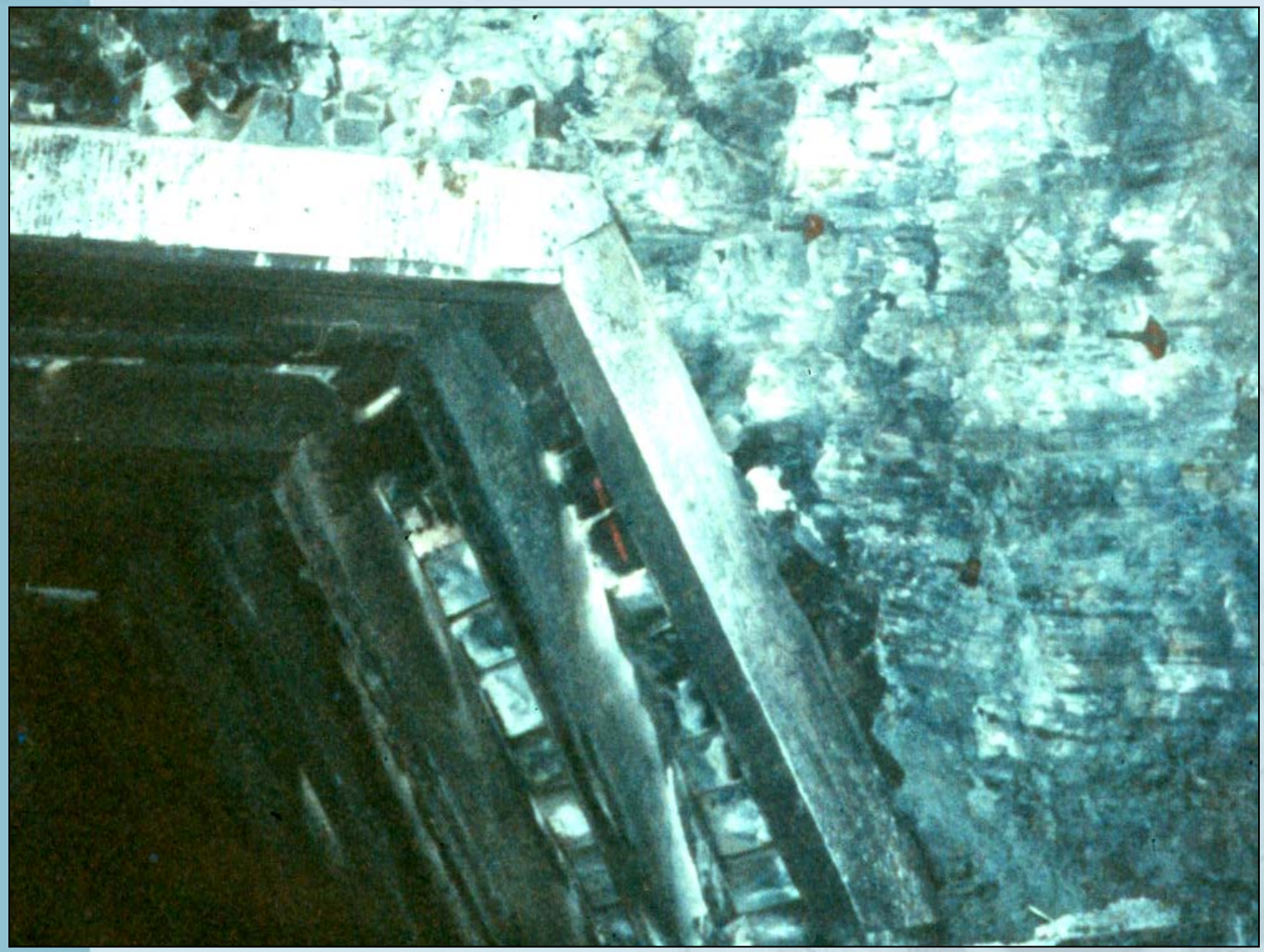
Initial Repairs – Scaling and Rock Bolting



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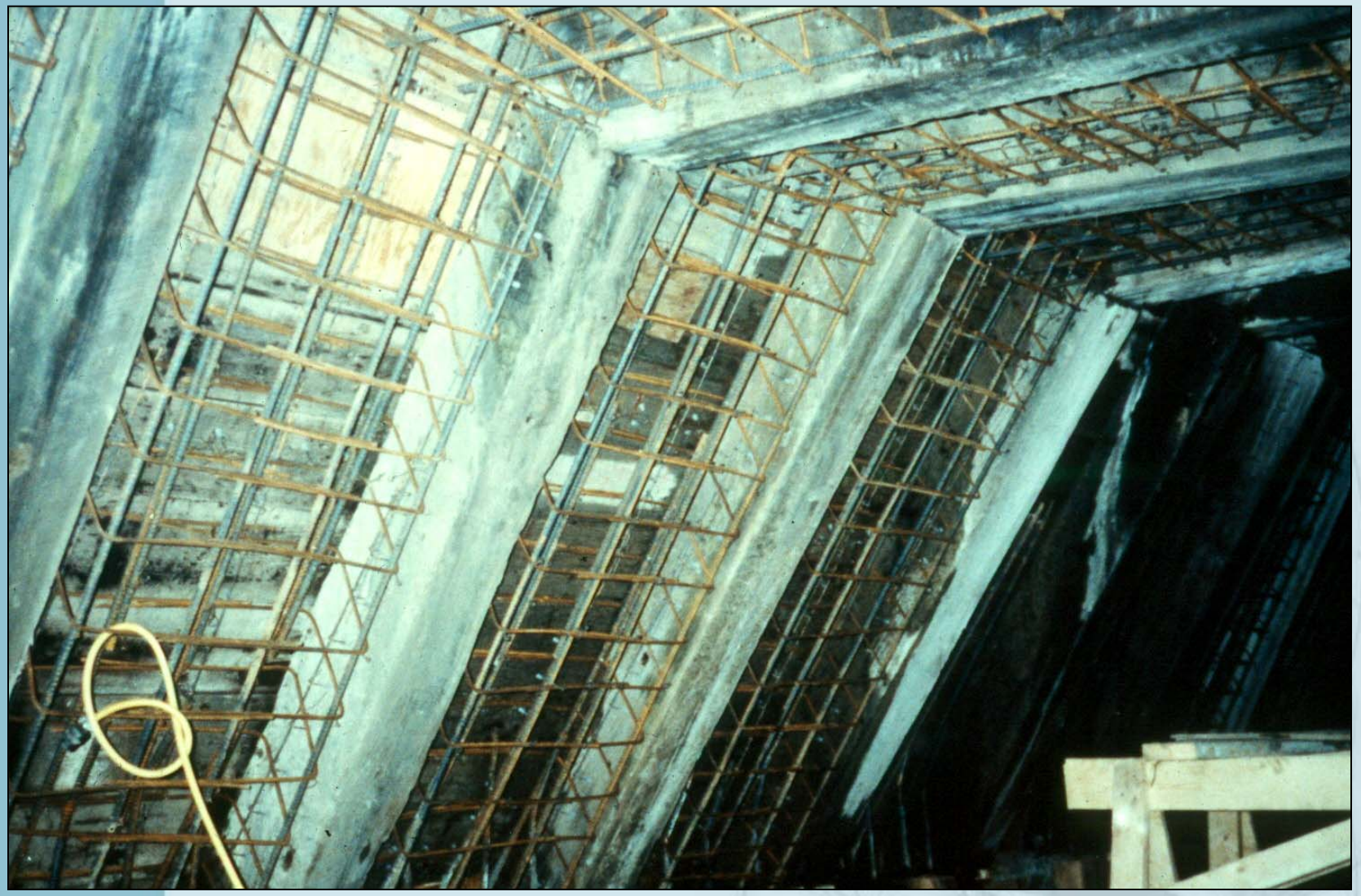
Concrete Reinforcing of Wooden Sets in Problem Areas



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CLEARANCE IMPROVEMENT AND STABILIZATION OF WHITEHAVEN AND ROCKPORT TUNNEL

CONRAIL - POCONO MOUNTAINS, PENNSYLVANIA

All work had to be done in 6 to 8 hour windows and track had to remain live at end of each shift

IINITIAL ICE CONDITIONS AT NORTH PORTAL OF ROCKPORT TUNNEL

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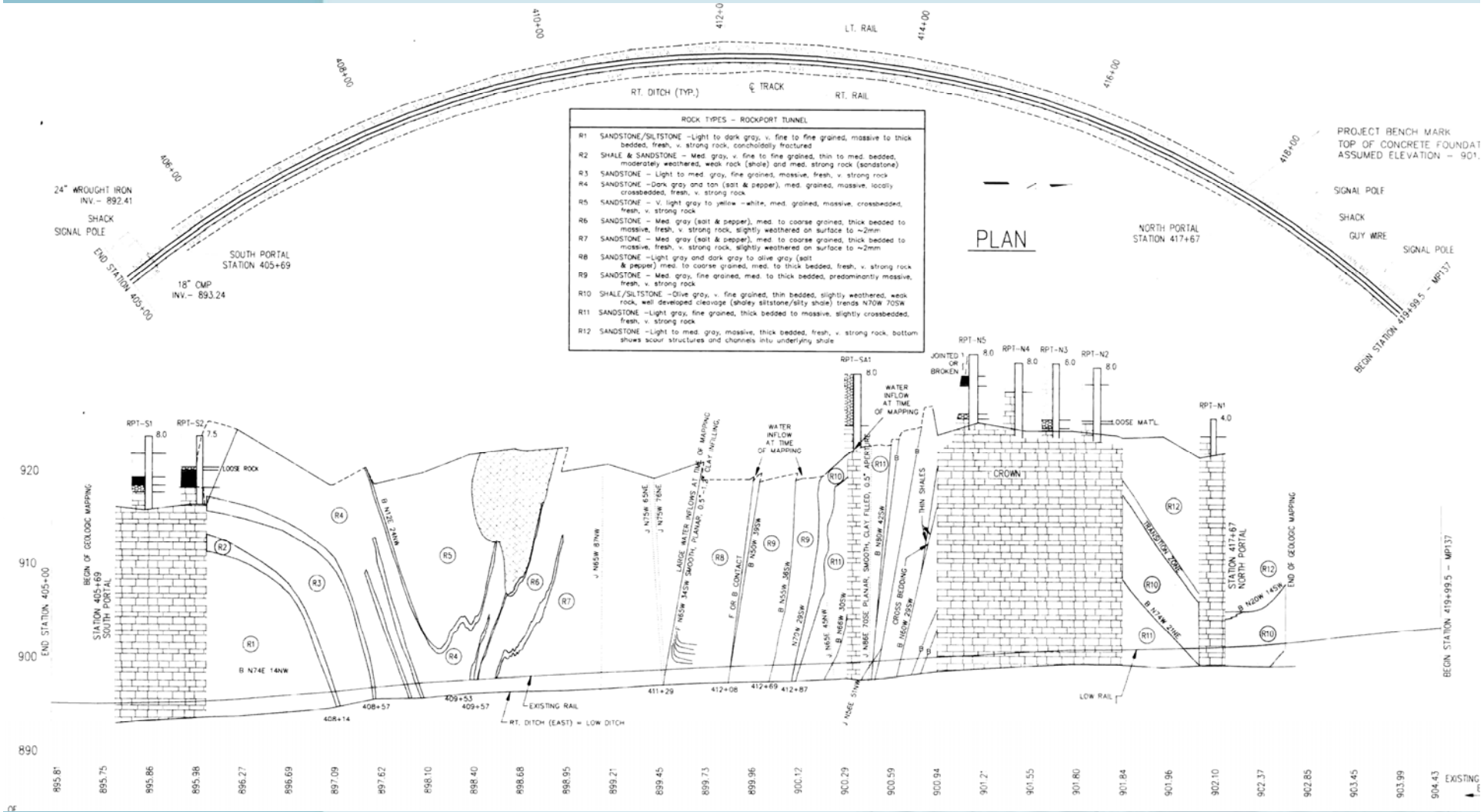
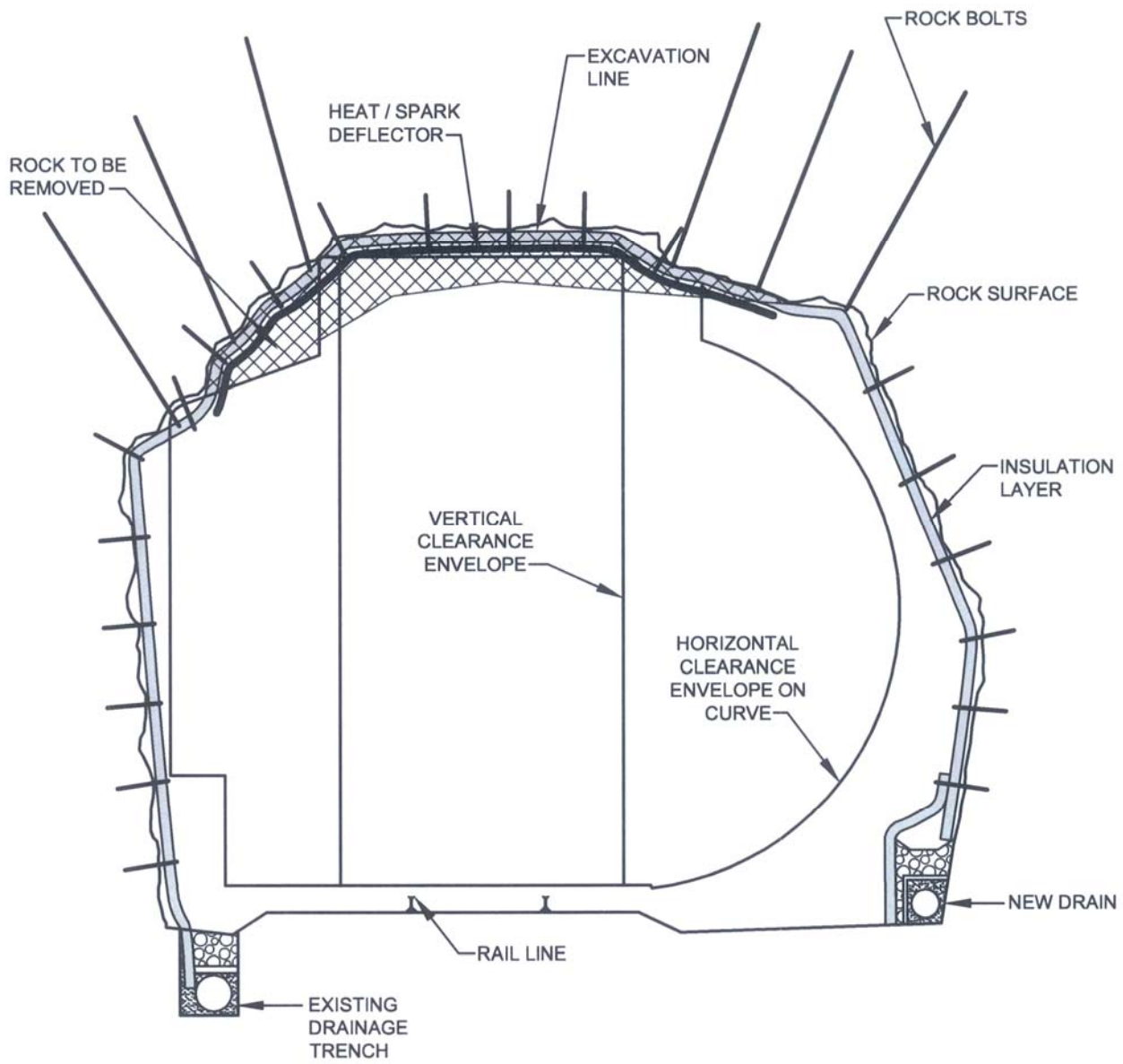
Plan and Profile of Rockport Tunnel Condition Survey



Step 1 – Condition Survey

Rockport Tunnel
Required Clearance Improvement



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Greatest Danger at North Portal!

Tom Badger - Miner

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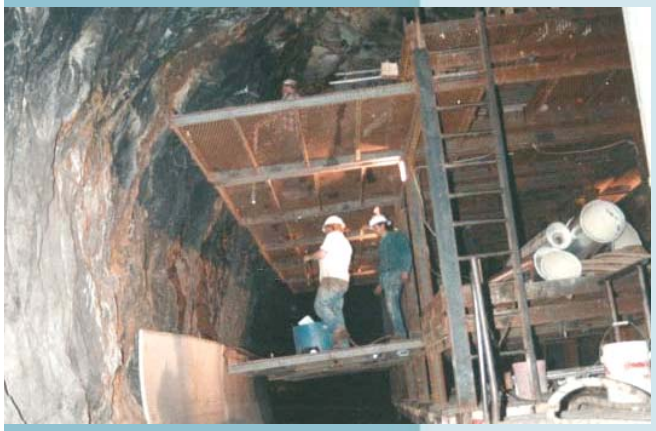
ROCKPORT TUNNEL

Pre-Support Then
Removal of
Structurally Unsound
Lining

Stabilizing Existing Lining Where Possible



Rock Bolting from
Work Platform

Stabilizing with Fiber Reinforced Shotcrete

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Whitehaven Tunnel
Notching Crown to Increase Clearance

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WHITEHAVEN TUNNEL

Re-blasting of cuts due to insufficient extent of roadheader notch

CONRAIL -

WHITE HAVEN TUNNEL,
SOUTH PORTAL

(No original portal structure)

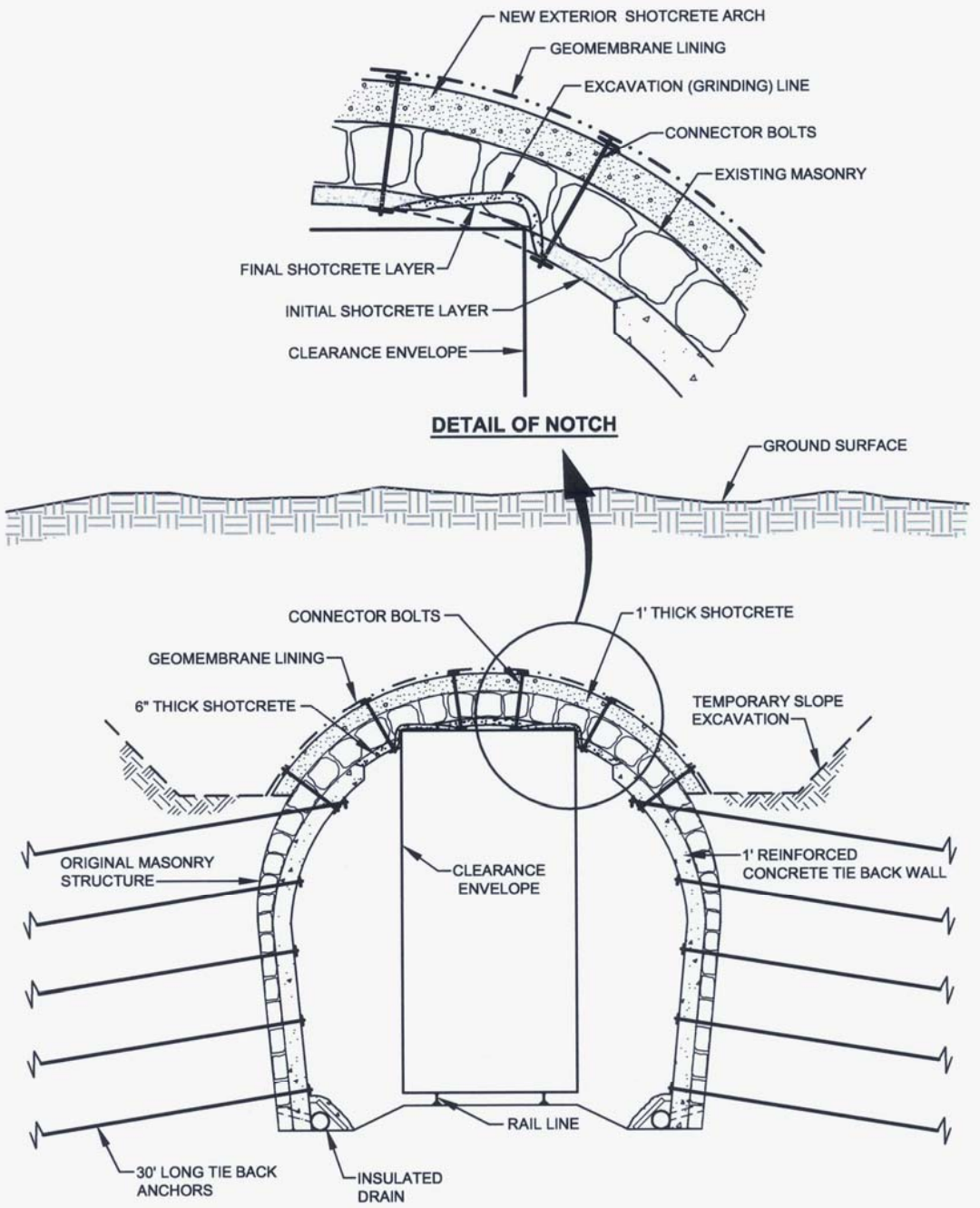
Initial support with rockbolts;

Final support with fiber-reinforced shotcrete

WHITEHAVEN TUNNEL

Clearance Improvement at North Portal

Historic Portal Structure



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WHITE HAVEN TUNNEL

Support and Reinforcing of North Portal Walls

- Reinforced shotcrete lining

- Core through lining prior to anchor installation

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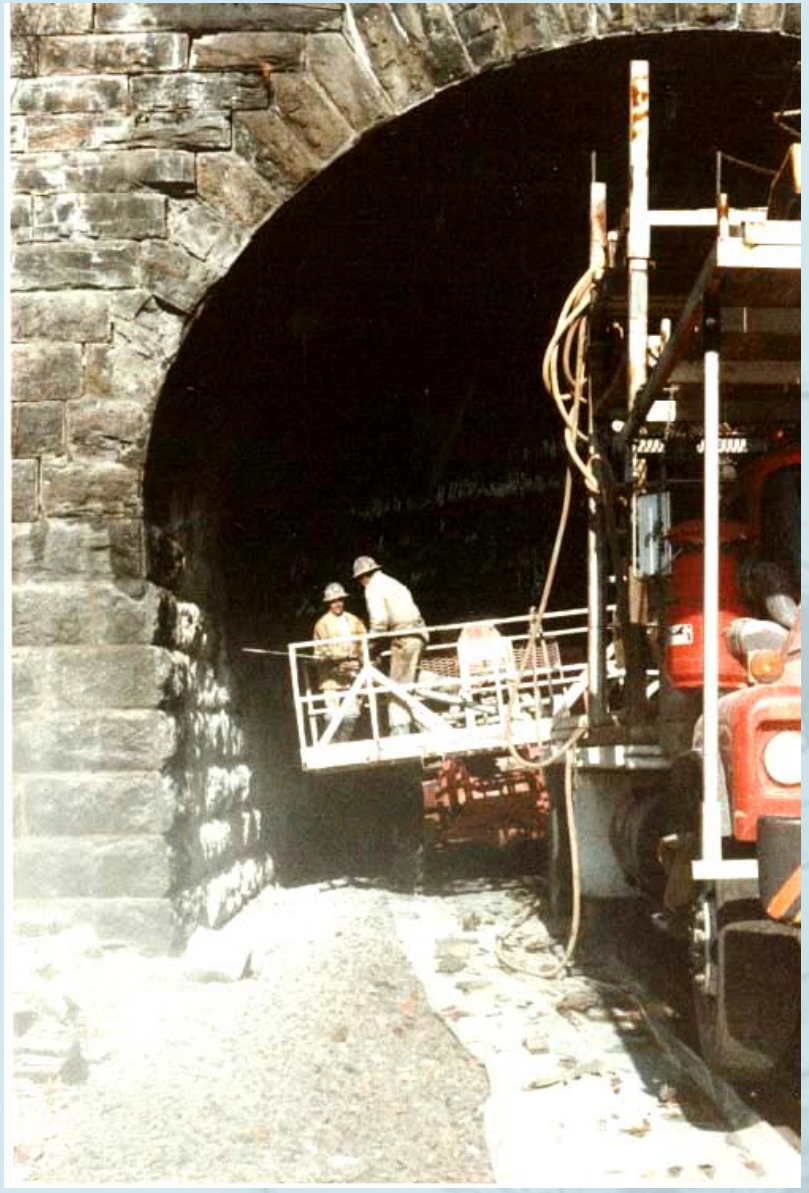
Whitehaven Tunnel Stabilizing Portal

Drilling Rock Anchors in Masonry Wall



CONRAIL -

WHITE HAVEN TUNNEL

NORTH PORTAL

Excavation of Tunnel Cover

Support with bolts and shotcrete

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WHITE HAVEN TUNNEL

SUPPORT OF NORTH PORTAL STRUCTURE

- Drainage Installation
- PVC Liner

CONRAIL -

WHITE HAVEN TUNNEL

Saw notching of reinforced portal area

Tunnel Ice and Drainage Problems

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Tunnel Drainage

Construction of Insulated Drains

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Conrail -

White Haven Tunnel

Insulation in an Irregularly - Shaped Section of the Tunnel

- Rail - Mounted Work Deck
- Insulation in a Regularly - Shaped Section of the Tunnel
- Spark Deflector Installation

CONRAIL WHITE HAVEN AND ROCKPORT TUNNELS

INSULATION SPARK DEFLECTOR INSTALLATION

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WHITEHAVEN TUNNEL
CONSTRUCTION CONDITIONS

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The Port Authority of NY and NJ

Downtown Restoration Program – Phase I
Exchange Place Improvements Project
City of Jersey City, NJ, USA

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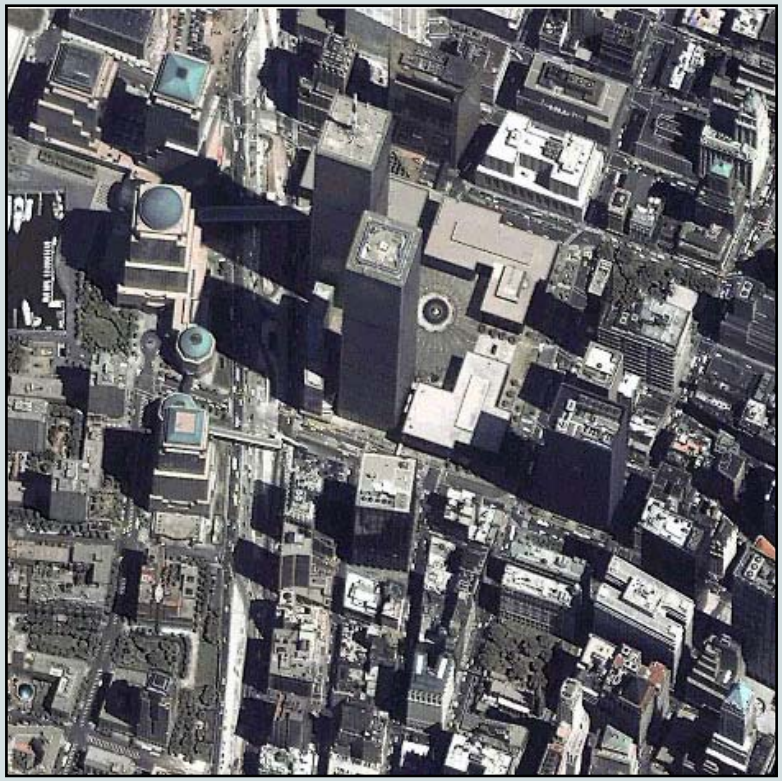
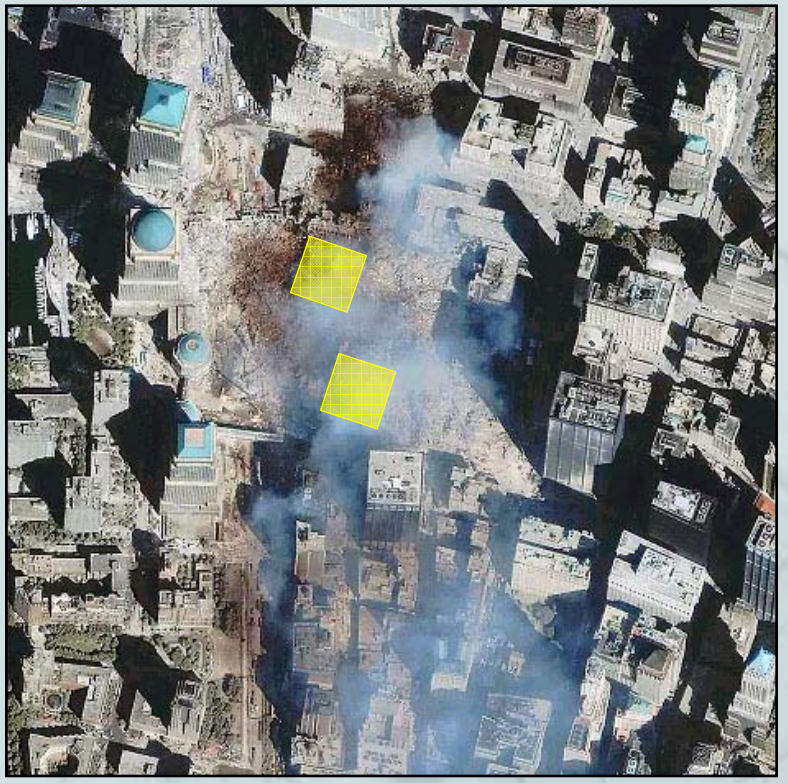
Recalling September 11, 2001

Recalling September 11, 2001

Recalling September 11, 2001



Before



After

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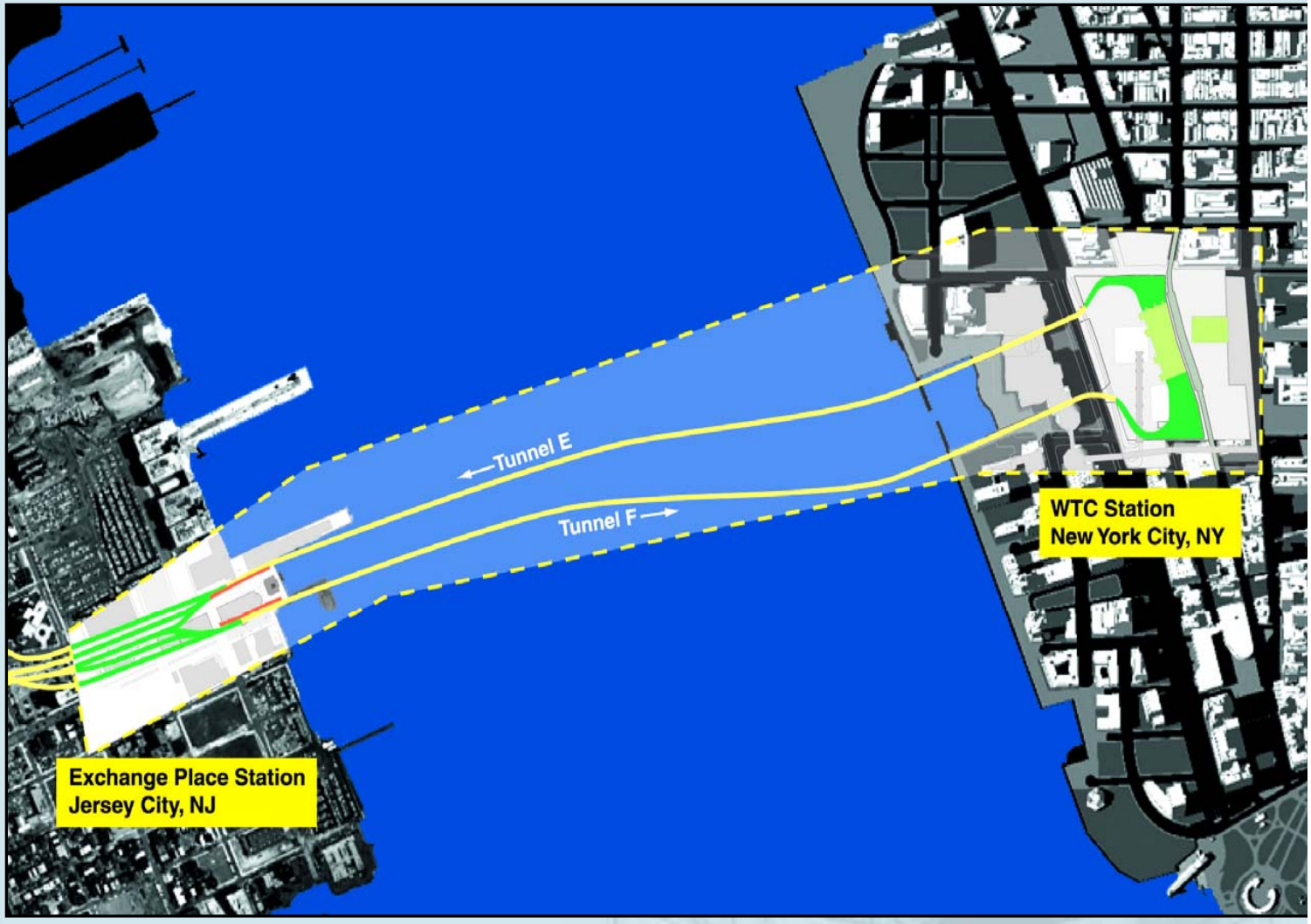
Downtown Restoration Program

- **Immediate Issues:**
  - WTC Station Destroyed
  - Tunnels E & F Plugged to Prevent Flooding
  - Exchange Place Station Closed
- **Phase I:**
  - New, Temp WTC Station
  - Rehabilitate Tunnels E & F
  - Covert EPS to be Terminal Station
- **Schedule:**
  - Re-Open EPS by June 2003
  - Re-Open WTC by Dec 2003



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Exchange Place Improvements Project

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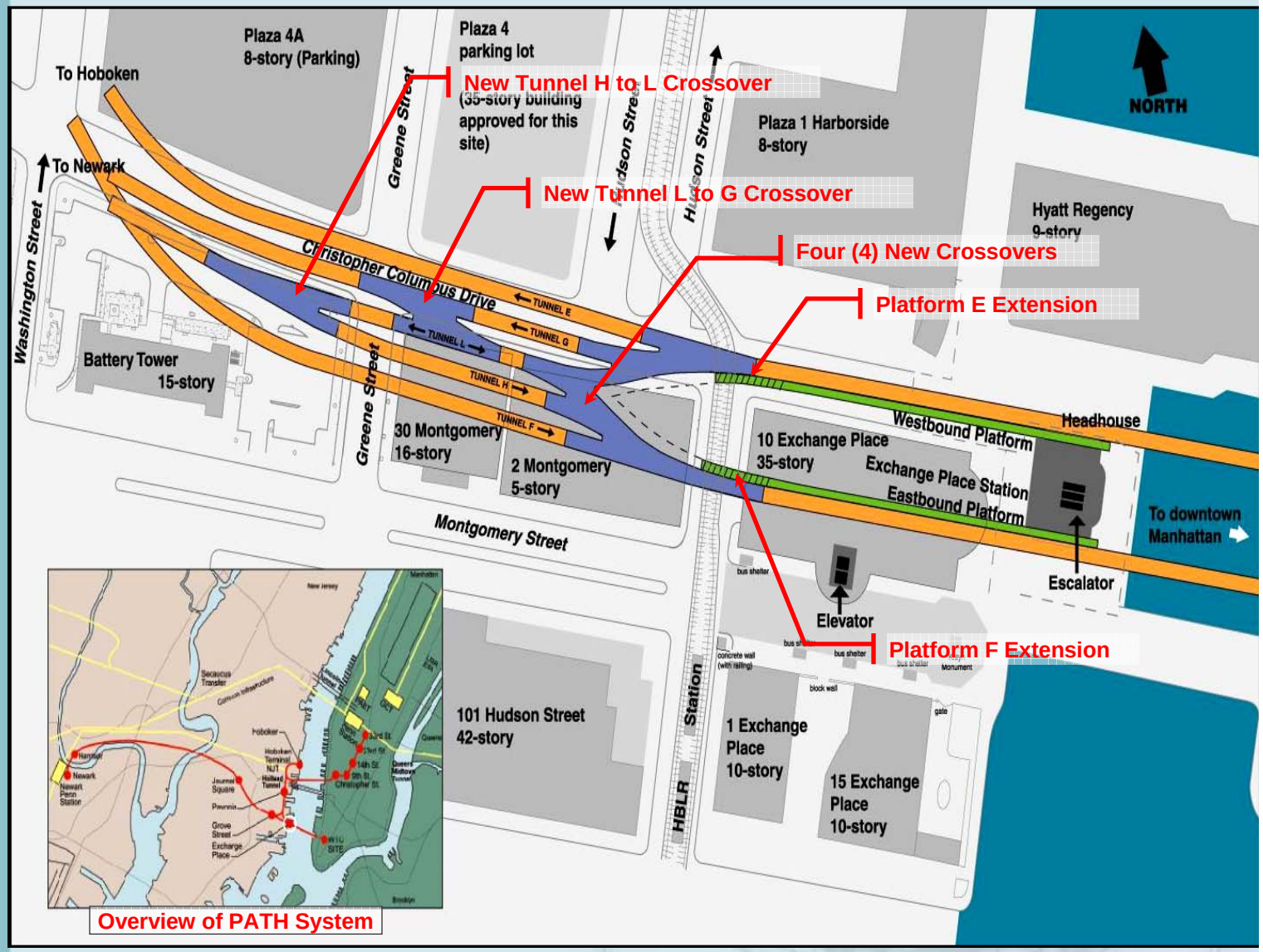
Scope of EPS Project

- Demolish Tracks, Cables, Conduits, and Equipment
- Construct New Crossover Tunnels
- Extend Station Platforms
- Install New Duct Banks, Cables, and Equipment
- Install New Tracks, Turn outs, Signal Controls
- Restore Station



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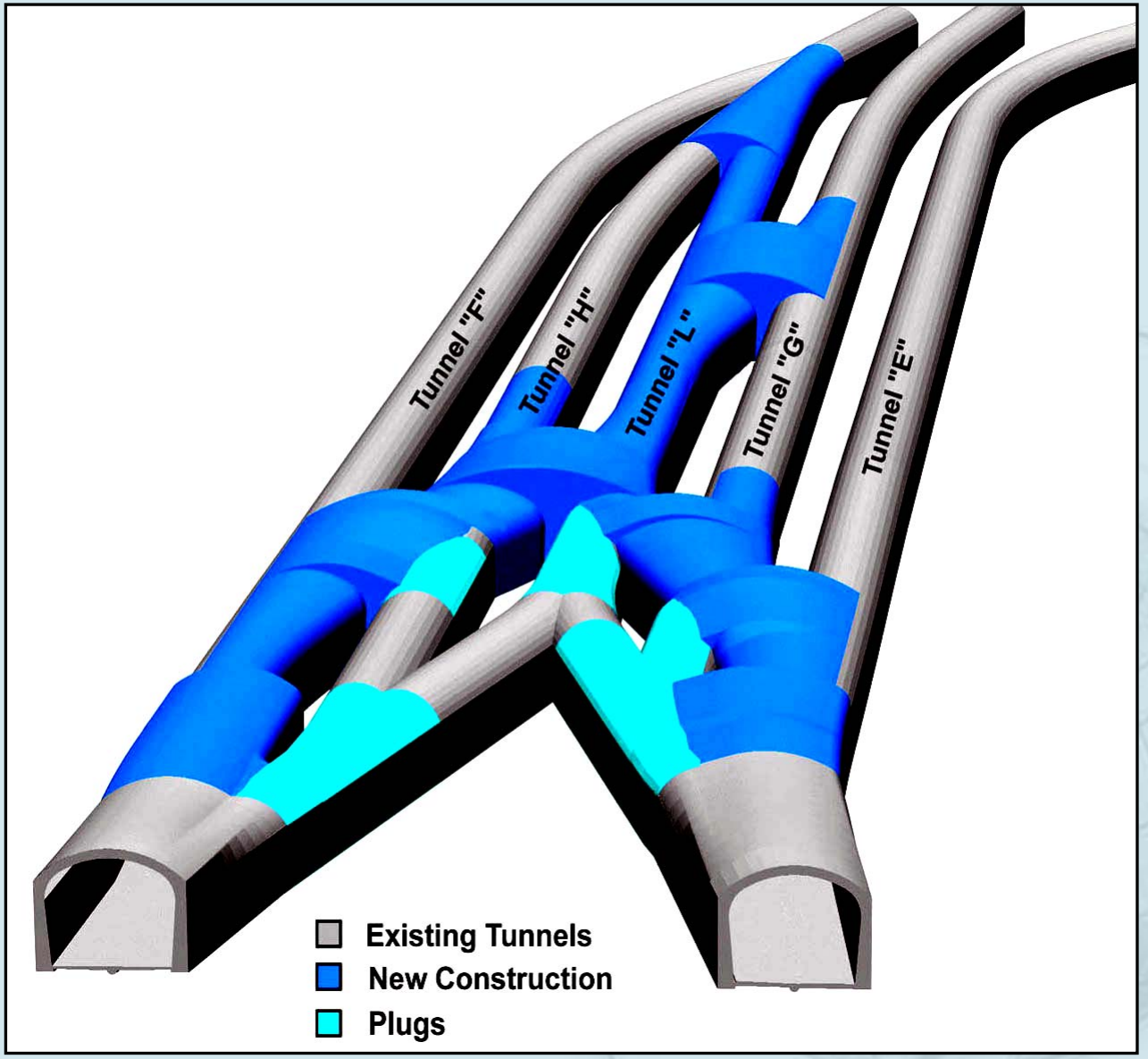
3D Rendering of Tunnels and New Cross Passages



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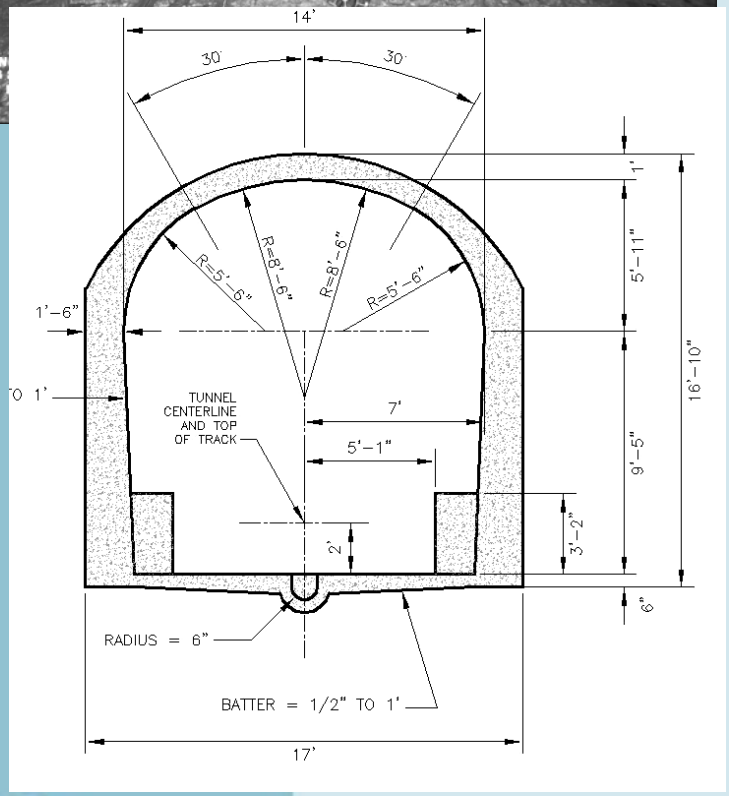
1907 Tunnels



Typical Section

Condition Survey

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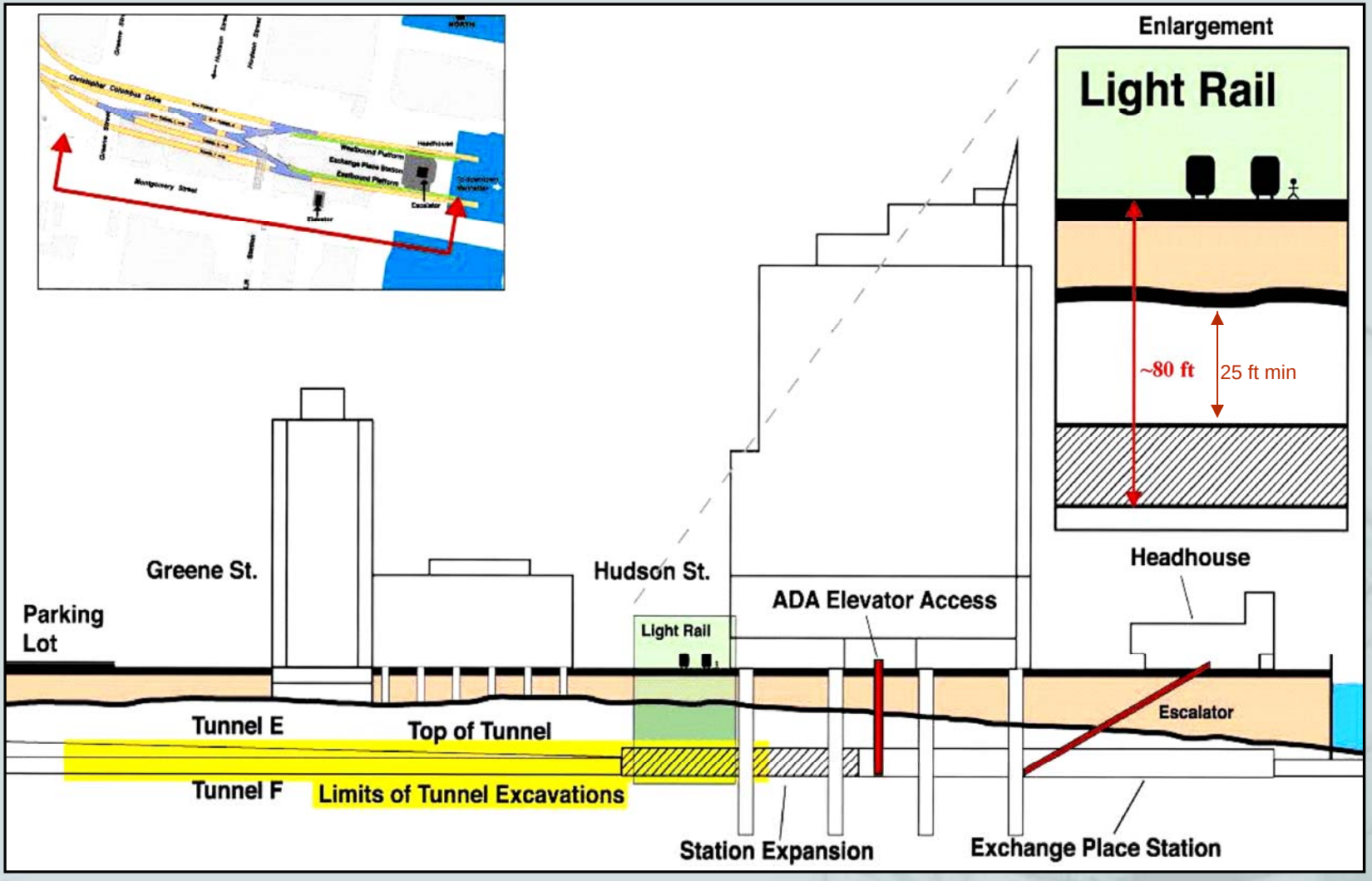
Profile through Tunnels



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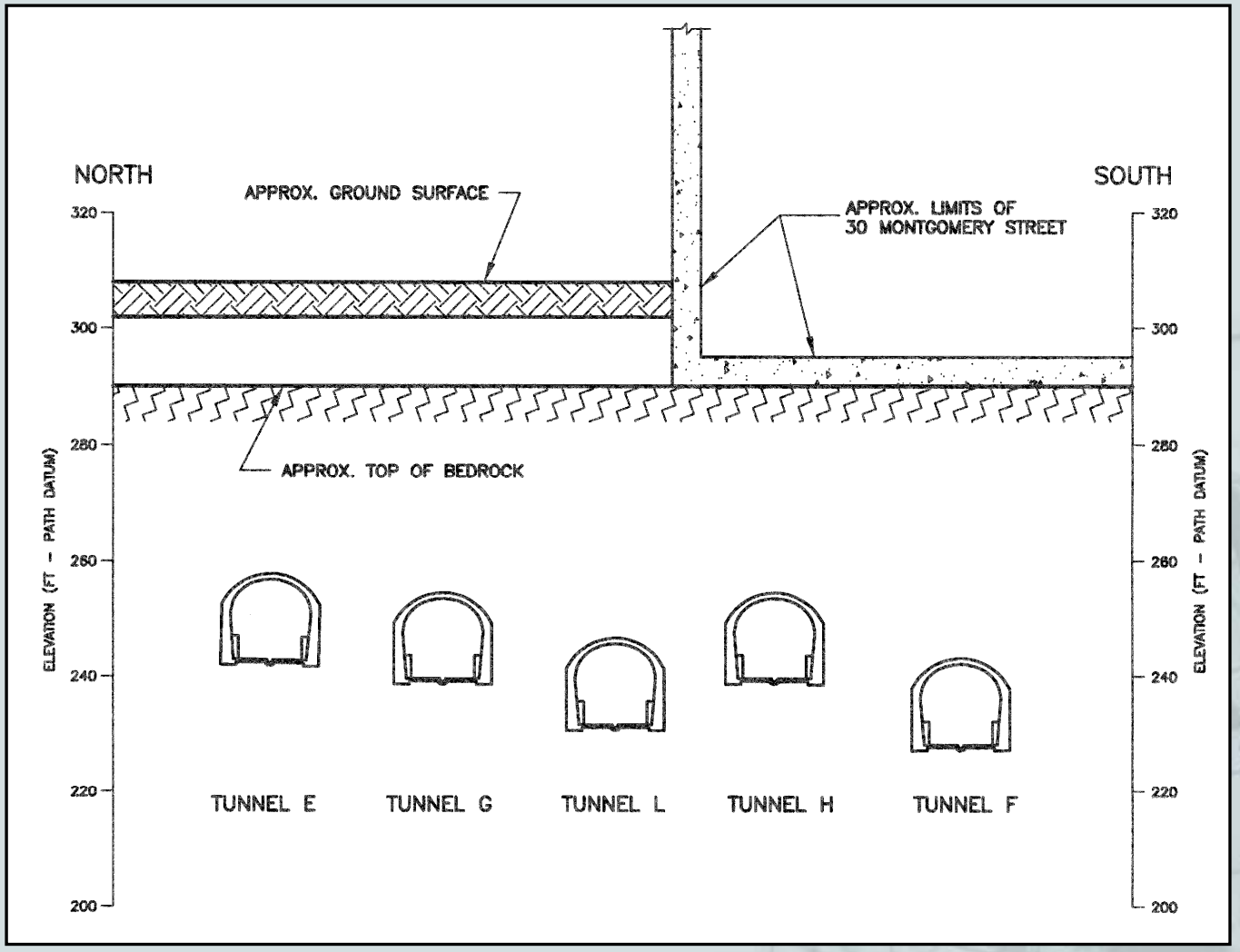
Typical Cross Section



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Jersey City Streets Above Project

Christopher Columbus Boulevard

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Project Challenges

- **Schedule, Schedule & Schedule**
  - Complete Station Renovations within 15 months
  - Complete Tunnel Excavation Activities within 7 to 8 months
  - Undertake and Complete Investigations and Designs Parallel with Construction
  - Commence Construction Before Investigations and Designs Completed
  - Balance Project Schedule Demands & Design Conservatism

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Design and Construction Challenges

- Excavate Large Underground Rock Caverns Up to 60 feet wide in the Manhattan Schist
- Shallow Rock Cover, as thin as 25 feet
- Localized Zones of Poor Rock Quality
- Lower than Expected Rock Mass Strength
- Overlying Multi-story Building Structures
- Limited/Restricted Access for Construction
- Narrow Tunnel Clearances

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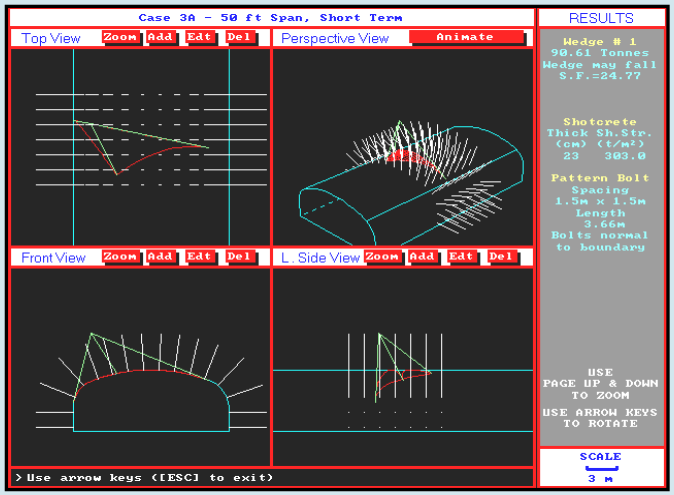
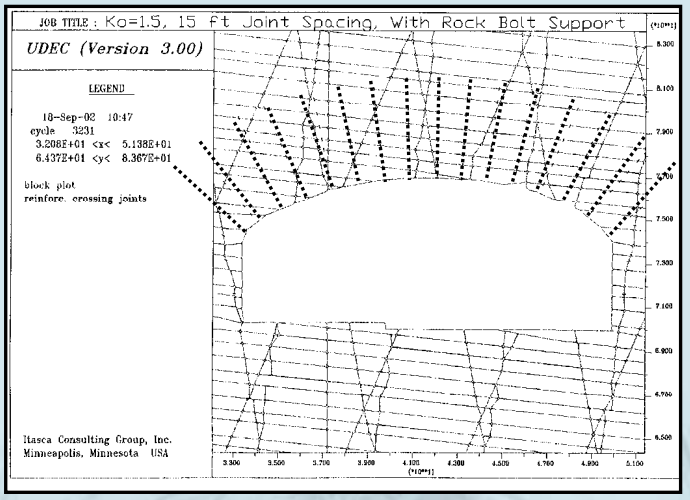
Tunnel Analyses

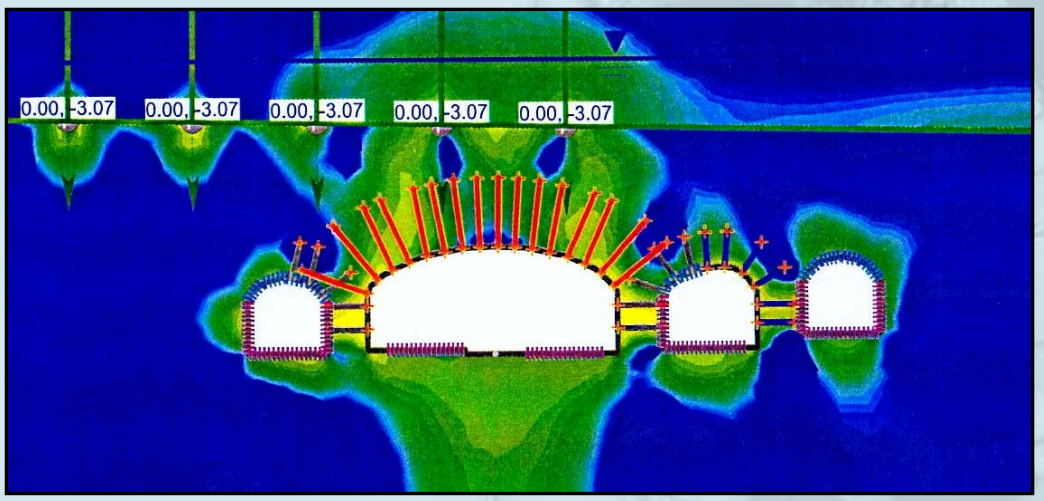
- **Analyses:**
  - **UNWEDGE**
  - **Phases²**
  - **UDEC**



UNWEDGE



UDEC



Phases²

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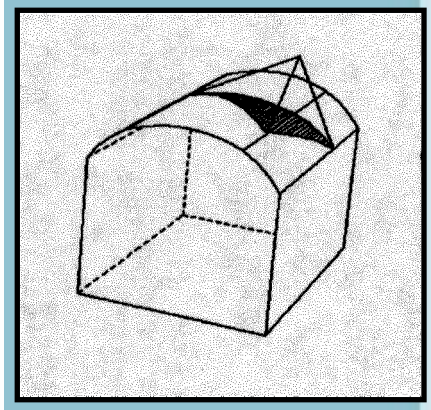
Conclusions from Analysis

- Stresses changes are negligible
- Maximum crown displacements estimated at ¾ inch
- 15 foot long rock bolts alone provide factor of safety >1.0 for worst-case wedges and >1.5 for observed wedges
- 11 inch min. thickness of fiber-reinforced shotcrete and lattice girders increase long-term factor of safety to >3



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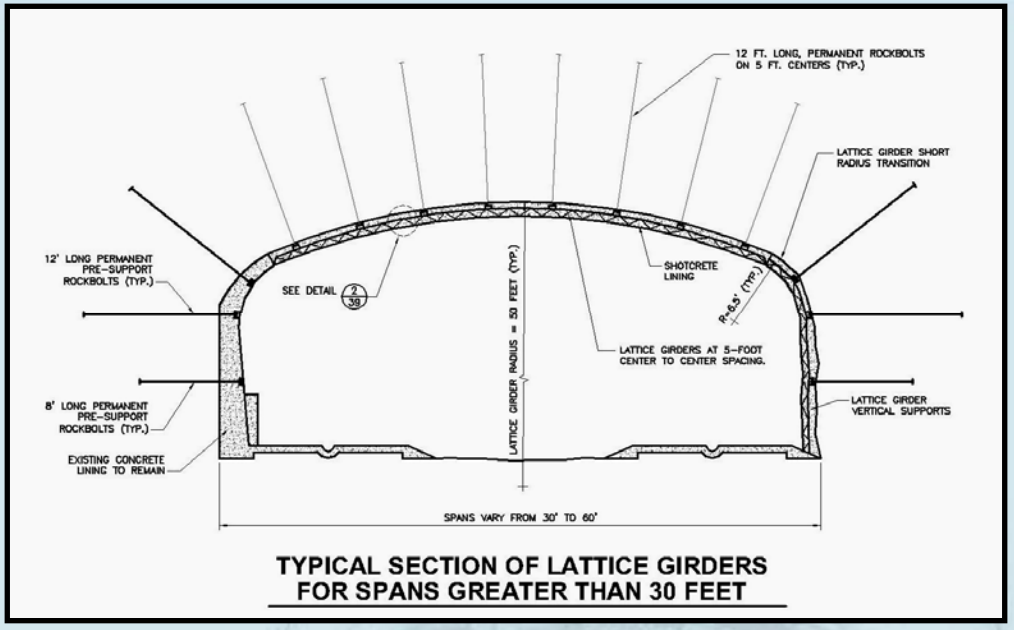
Tunnel Design

Initial Design Decisions:

- Steel Fiber Reinforced Shotcrete & Resin-Grouted Rockbolts for Permanent Support
- Drill-and-Blast, with Line or Channel Drilling in Critical Locations
- Flat Arched Roof
- Pre-Support Reinforcement
- Staged Excavation & Support Installation
- Concrete Backfill in Plugs



TYPICAL SECTION OF LATTICE GIRDERS FOR SPANS GREATER THAN 30 FEET

Later Design & Construction Decisions:

- Bolt Length & Spacing
- Shotcrete Thickness
- Road-Header Excavation

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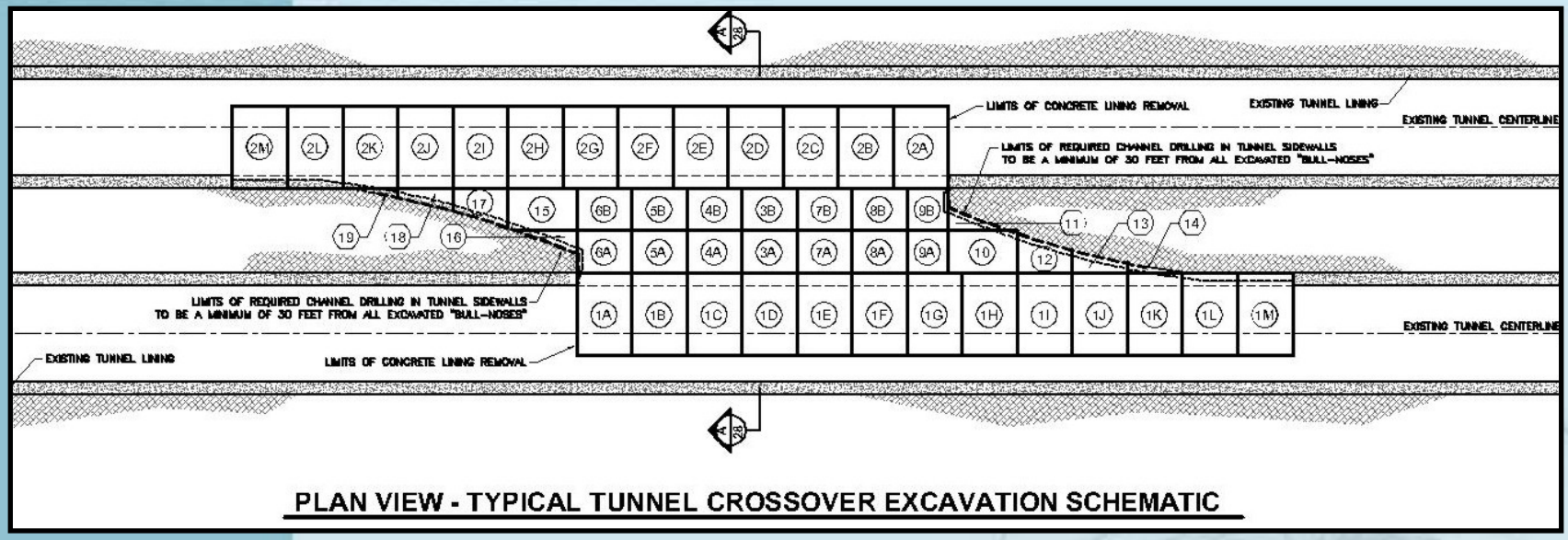
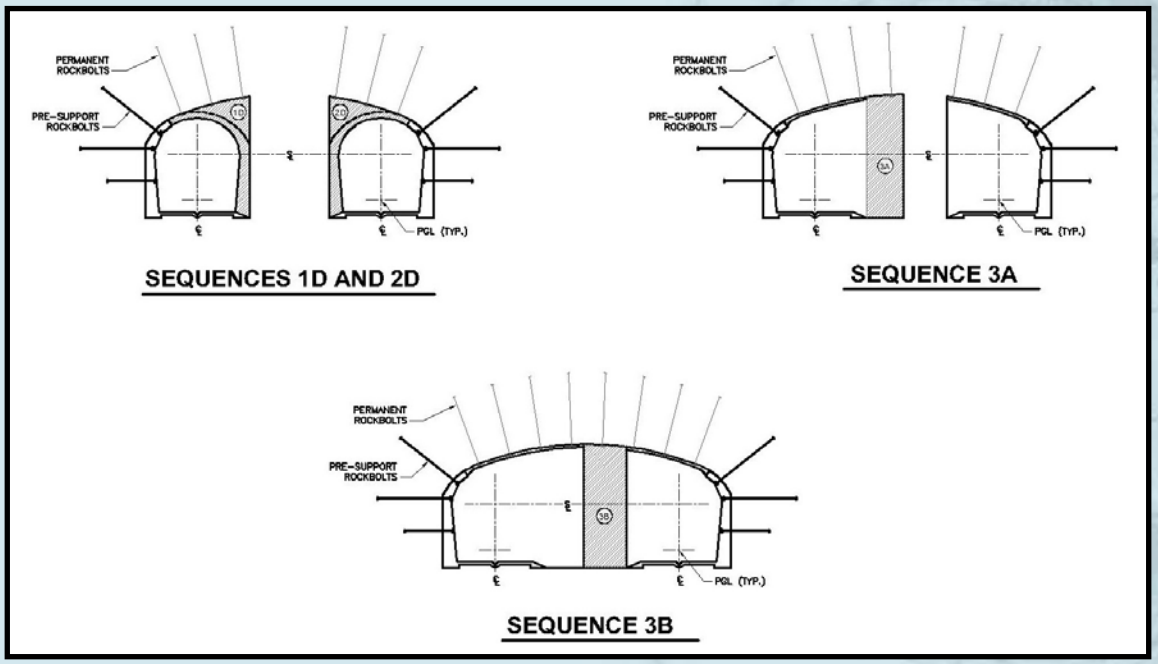
Generalized Tunnel Excavation & Ground Support Installation Sequences



PLAN VIEW - TYPICAL TUNNEL CROSSOVER EXCAVATION SCHEMATIC



Pre-Support Reinforcement

Concrete Liner Removal

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Tunnel Plugs

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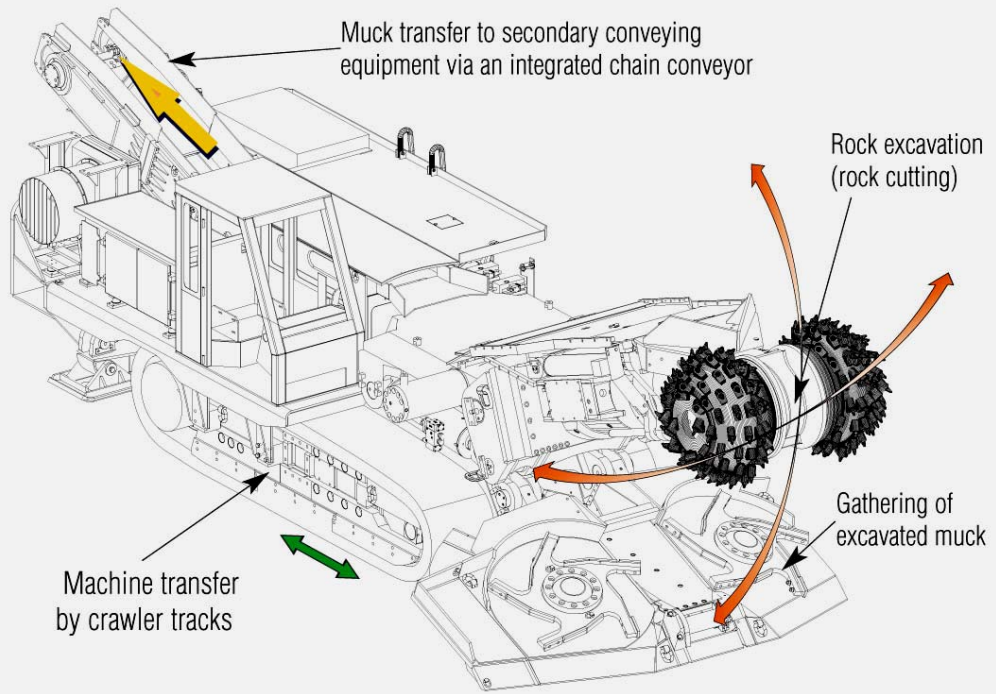
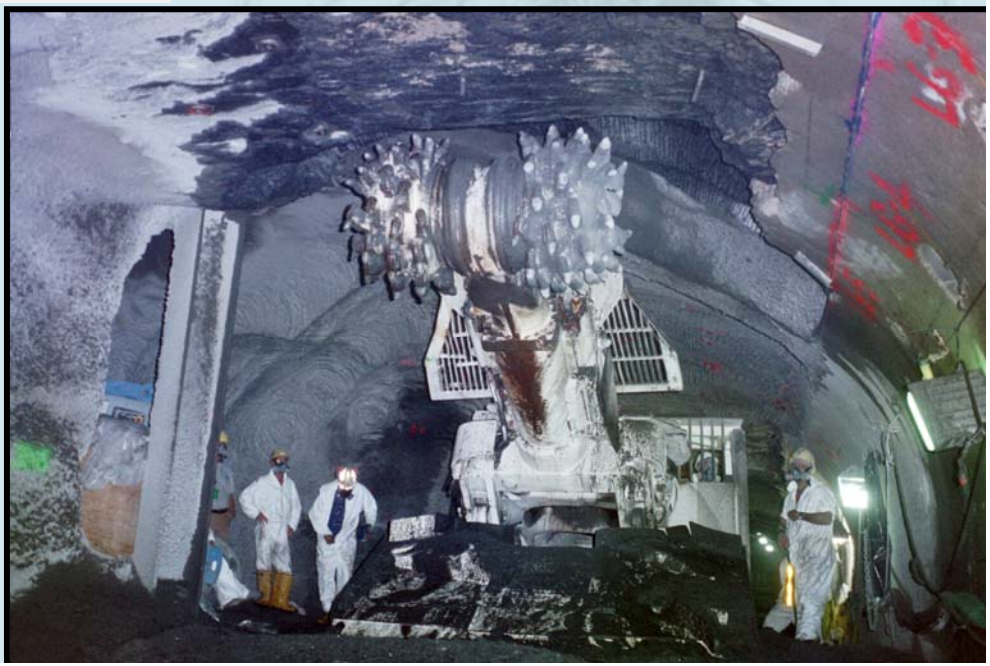
Road-Header Excavation





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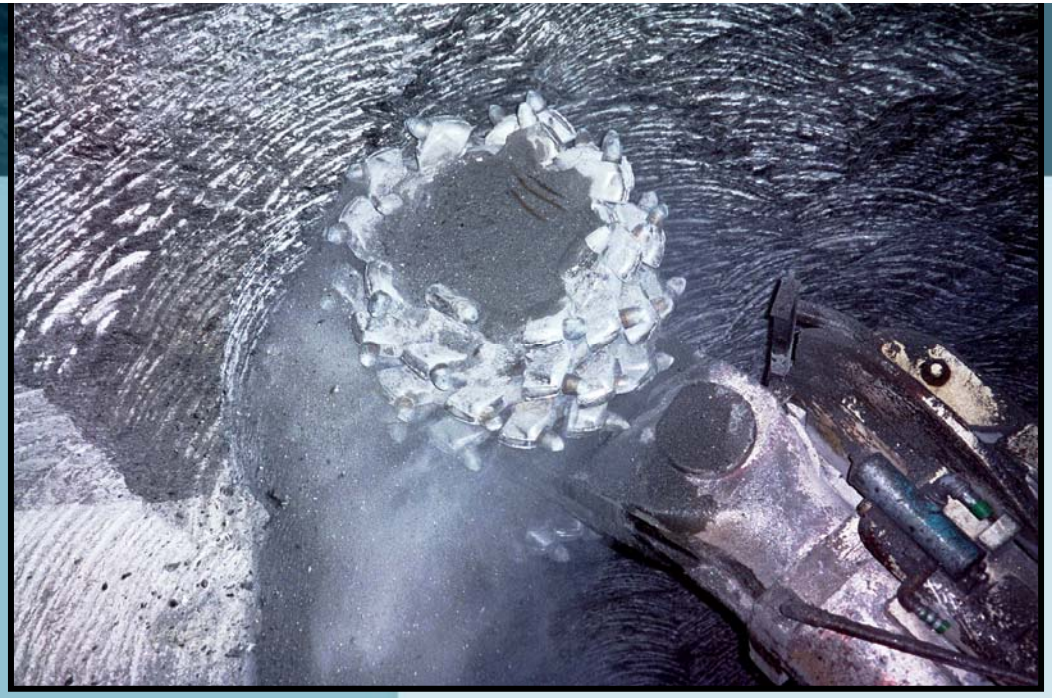

Road-Header Excavation (Cont'd)

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Rock Bolt Installation

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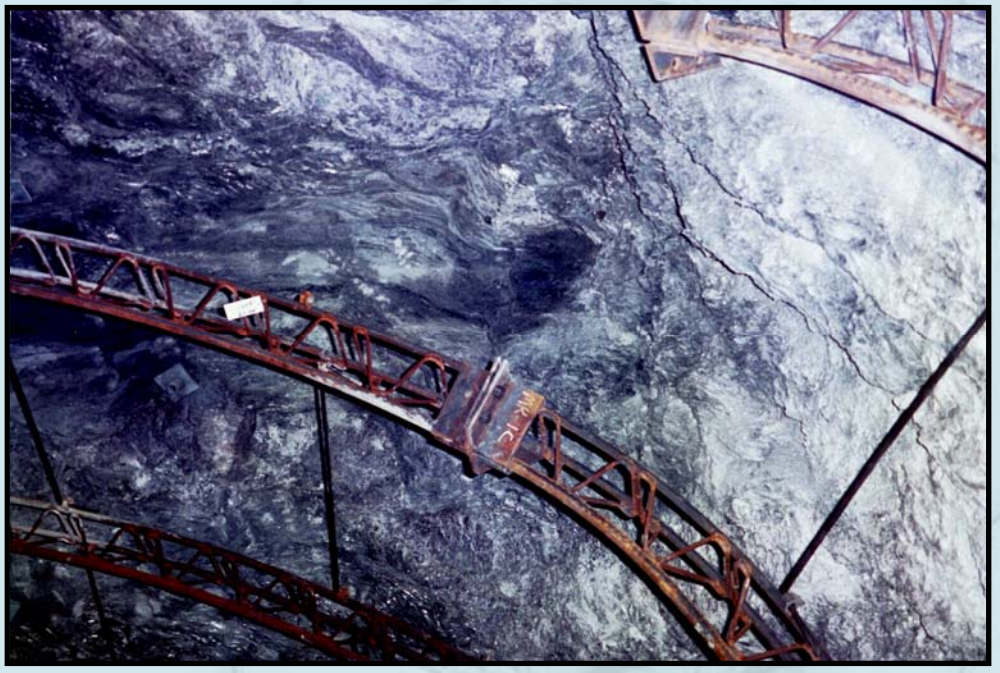
Lattice Girder Support



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Shotcrete Application

Note: The Use of Shotcrete as a Final Lining saved 6+ months on the Project Schedule

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Final Shotcrete Lining

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Nearing Completion

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Completed Crossovers

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Completed Crossovers

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Completed Crossovers

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Thanks for your attention